Load tests on high capacity caissons founded on decomposed rock

Essai de chargement sur des caissons de grande capacité fondés sur de la roche altérée

D.C.KOUTSOFTAS, Associate, Dames & Moore, San Francisco, California, USA
L.C.REESE, Professor of Civil Engineering, University of Texas, Austin, USA

SYNOPSIS: The results of five load tests on large diameter caissons founded on decomposed rock are presented and analyzed. The caissons ranged from 2.3 m to 2.5 m in diameter and were 20 m to 28 m long. Two of the load tested caissons were founded on decomposed mica schist, while the other three were founded on decomposed granite. The caissons founded on decomposed mica schist were loaded to twice the design load or to failure, whichever occurred first, with corresponding loads of 24.5 MN and 26.7 MN. Both caissons could support substantially higher loads than anticipated. The caissons founded on decomposed granite were loaded to maximum loads ranging from 22 MN to 34 MN. None of the caissons showed signs of failure, although one caisson settled substantially more than the others. Detailed analyses of the results of the tests form the basis for estimating design parameters, including skin friction and end-bearing values.

INTRODUCTION

Caissons founded on rock are commonly used to support heavy column loads. It is historically rare to found caissons supporting heavy loads on decomposed rock. However, in recent practice, caissons have been increasingly founded on decomposed rock (both deliberately and unintentionally). In such cases it is necessary to evaluate the load-deformation behavior of the caissons and determine whether remedial action is necessary. This paper presents the results of 5 load tests on high capacity caissons founded on decomposed rock, and provides estimates of characteristics of the decomposed rock.

The load tests were performed as part of the investigation to evaluate the load-deflection characteristics of the existing caissons and to assess the need for remedial measures.

Two of the load tests were performed on caissons founded on a layer of decomposed mica schist overlying more competent material below. The other three caissons were founded on decomposed granite.

The results of the load tests were analyzed to develop parameters which may be useful in evaluating the load-deflection characteristics of caissons founded on weathered rock.

CAISSONS FOUNDED ON DECOMPOSED MICA SCHIST

The caissons were constructed in a major city in the northeastern United States and were originally designed to be founded on sound mica schist, forming the foundations of a 22-story building. In general, the subsurface conditions below the basement of the structure were as follows. The first stratum is a layer of dense heterogeneous alluvium, consisting of interbedded fine to medium sand, silty sands, and occasional silt layers approximately 15 m thick. A very dense sandy gravel layer was usually encountered at the lower 1.5 m to 2.5 m of the alluvium. Below the alluvium is the decomposed mica schist, a soil-like material with standard penetration resistances in the range of 15 to 50 blows/300 mm. The decomposed mica schist ranges in thickness from 6 m to 9 m and typically becomes denser with depth. It gradually grades into soft, then medium hard and finally sound mica schist.

Typical subsurface conditions below the two caissons, as determined from the results of core holes drilled through the caissons, are shown on Figure 1. Core recovery and rock

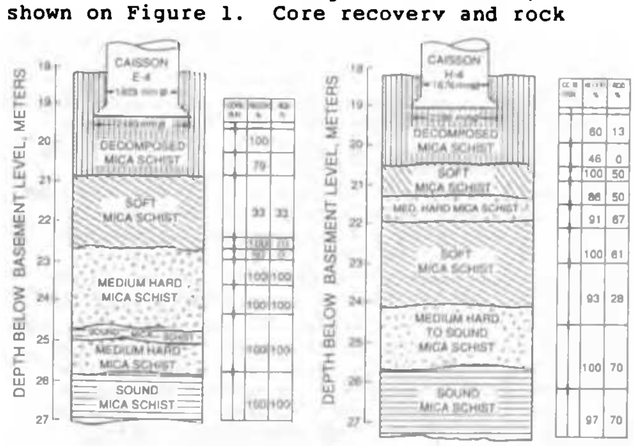


FIGURE 1 SOIL CONDITIONS BELOW CAISSONS FOUNDED ON DECOMPOSED MICA SCHIST

quality designation data are presented. A layer of decomposed mica schist approximately 1.5 m thick was present below each of the two caissons. Soft to medium hard mica schist with RQD values in the range of 30%-70% was present below the decomposed mica schist.

Each of the caissons supported a single column with design loads of 13.5 MN and 16.4 MN, respectively. The load tests were performed by first lifting the column by jacking against the existing caissons. Then additional loads were transferred to the caissons from a loading frame jacked against rock anchors penetrating a considerable distance below the base of the existing caissons.

The results of the load tests are shown on Figure 2. Caisson H-4 was load tested to twice the design load without any sign of impending failure. However, large deformations developed for Caisson E-4 at a load approximately 1.5 times the design load. The elastic compression of the shaft as measured from telltales is also shown and is essentially parallel to the theoretical elastic compression line. This is considered an indication that the vertical loads (above the initial existing loads) were essentially being transferred to the base of the caissons, with practically no reduction due to skin friction.

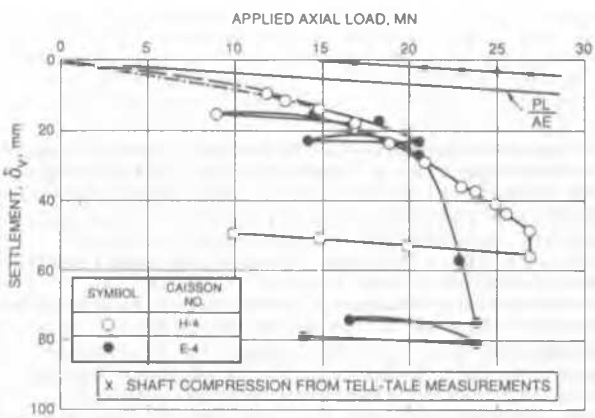


FIGURE 2 LOAD-DEFLECTION BEHAVIOR: PILES E-4 AND H-4 FOUNDED ON DECOMPOSED MICA SCHIST

The results of the load tests were analyzed to estimate base loads and base deflections and the results of the analyses are presented on Figure 3 as end-bearing pressure versus normalized base settlement. Using the maximum end-bearing pressure for Caisson E-4 as the limit and applying a conventional factor of safety of 3, the allowable end-bearing pressure for decomposed mica schist would be 0.80 MPa. Values higher than 1 MPa could be justified from the results of the load test on caisson H-4. These values compare well with values recommended by Peck (1969) for rocks with RQD less than 25%. It should be noted that the local city code allows 1 MPa design bearing pressure for the soft mica schist, with no reference to allowable bearing pressures in the decomposed mica schist.

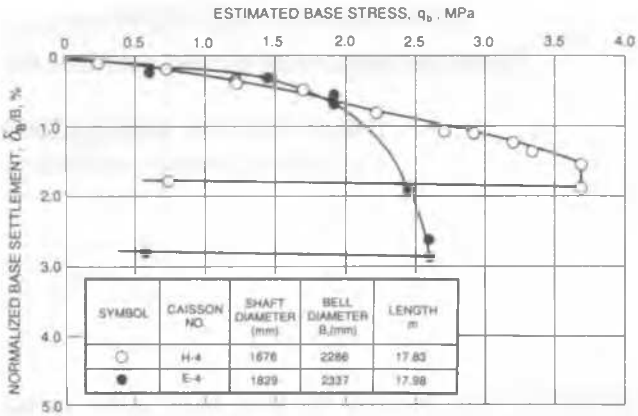


FIGURE 3 ESTIMATED BASE RESISTANCE VS. BASE MOVEMENT CAISSONS FOUNDED ON DECOMPOSED MICA SCHIST

Woodward, et al. (1972) cite presumptive end bearing values, commonly used in the area, in the range of 1.2 to 1.9 MPa for mica schist with penetration resistances greater than 60 blows for 150 mm. The material referred to by Woodward et al. would probably be equivalent to the soft to medium hard mica schist.

CAISSONS FOUNDED ON DECOMPOSED GRANITE

The caissons were constructed as part of the foundations of a six story ocean terminal. The subsurface conditions as determined from boreholes drilled adjacent (within 1 meter) to the load tested caissons are illustrated in Figure 4. A layer of loose to medium dense fill overlies natural sediments consisting of

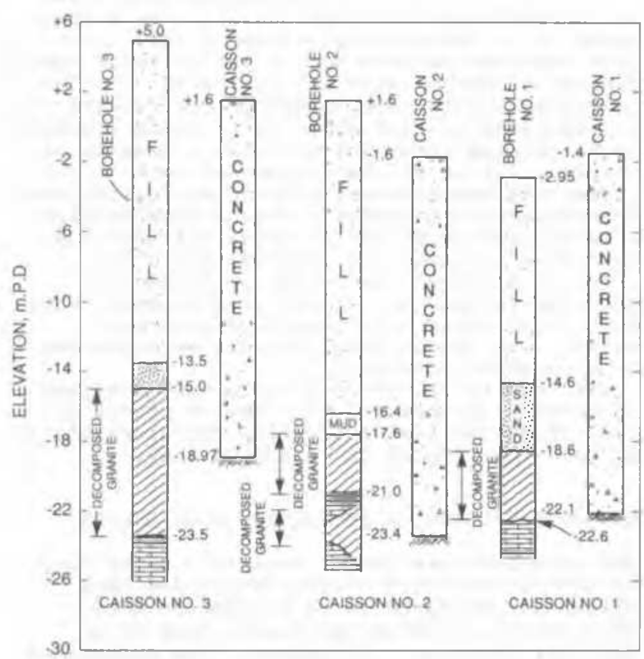


FIGURE 4 SUBSURFACE CONDITIONS ADJACENT TO LOAD TESTED CAISSONS

marine sand or soft marine mud. The marine sediments are underlain by decomposed granite, whose thickness and degree of decomposition are extremely variable even over short distances. The decomposed granite is extremely dense with SPT N values typically in excess of 200.

Figure 5 presents details of the foundation conditions below the base of each of the three load tested caissons, as determined from 4 to 5 core holes drilled through each caisson.

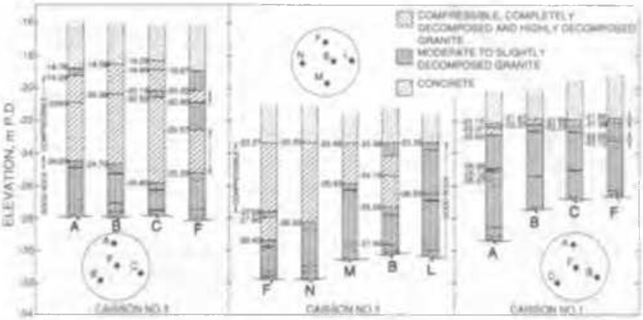


FIGURE 5 DETAILS OF FOUNDATION CONDITIONS BELOW THE LOAD TESTED CAISSONS

Decomposed granite was found at various levels under all the caissons, although Caisson No. 1 appeared to have only thin lenses of decomposed granite confined within better rock. Visual observations in hand excavated caissons at the same site revealed the presence of pockets of decomposed granite of limited lateral extent confined within good rock. It is also evident that Caisson No. 2 was partially supported on sound granite, although decomposed granite as thick as 4-6 meters was found under portions of the caisson. The most extensive weathering was found under Caisson No. 3.

The first two load tests were instrumented with strain gauges installed in holes cored through the caissons. The purpose of the instrumentation was to evaluate the load distribution with depth, as it was anticipated that the caissons might have significant frictional capacity.

The results of the load tests on Caissons No. 1 and No. 2 are shown on Figure 6. The caissons were loaded to 20.0 and 22.6 MN respectively in 4 to 5 load cycles, with the load increased progressively in each subsequent cycle. Reaction for the applied loads was obtained by jacking against the pile caps, to engage the weight of the superstructure.

Both caissons performed extremely well, with the total deflections less than 7 mm. The good performance of the caissons was primarily due to high frictional resistance within the decomposed granite layer above the base. The results of the load tests were analyzed to separate the base resistance from skin resistance. The strain gauge data showed very little resistance in the fill but there was considerable resistance along a short section of the caissons above the base, that apparently was acting as a socket in the decomposed granite. Figure 7 presents plots of skin friction in the socket versus socket movement. Values of skin resistance in the range of 300-400 kPa are evident. Figure 8 presents base loads versus base movement from the two caissons. Theoretical analyses indicate essentially elastic behavior with base moduli for the decomposed rock of about 500 MPa.

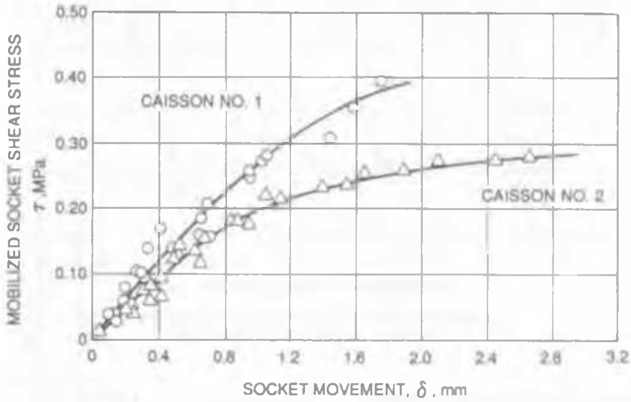
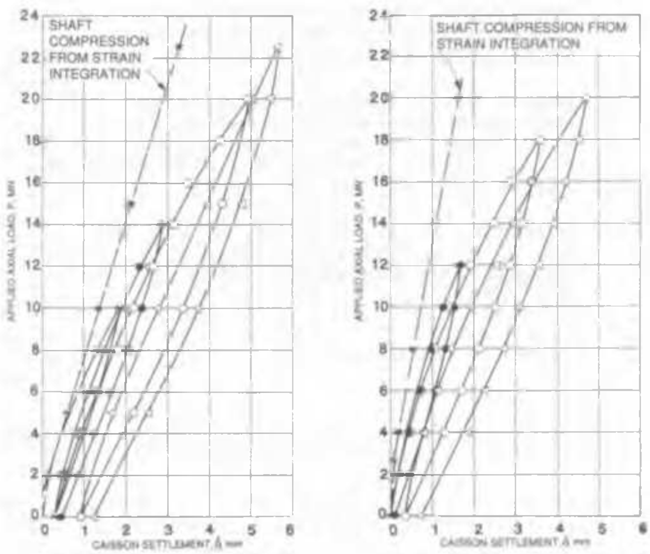


FIGURE 7 MOBILIZED SOCKET RESISTANCE



a) CAISSON NO.1

b) CAISSON NO.2

FIGURE 6 LOAD-DEFLECTION BEHAVIOR OF CAISSONS NO 1 AND NO 2

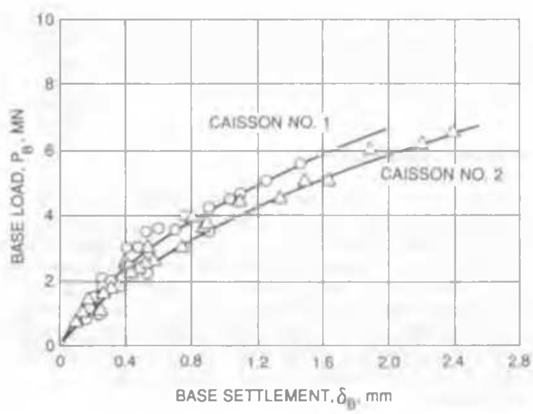


FIGURE 8 MOBILIZED BASE RESISTANCE

The results of the third load test are shown on Figure 9. Several cycles of loading were applied with the objective of precompressing the material below the base and minimizing post-construction settlements. Although the total settlement under the maximum applied load of 33 MN was 30 mm, the deflection during the last cycle of loading was only 8 mm, and the deformations are seen to be completely

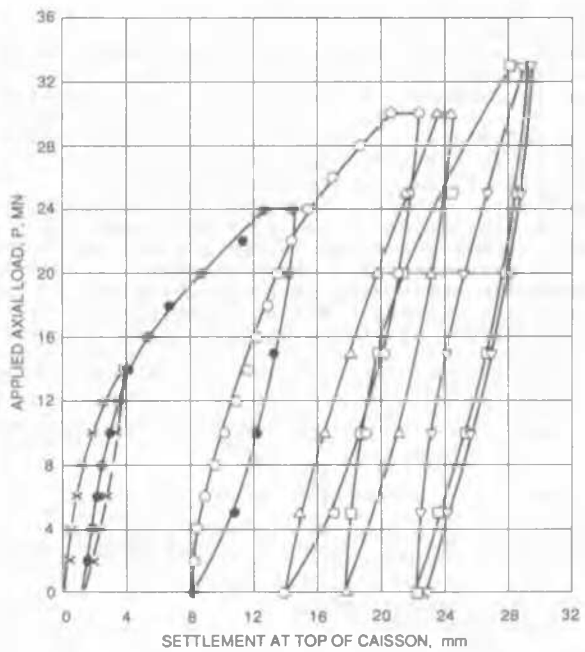


FIGURE 9 LOAD-DEFLECTION BEHAVIOR OF CAISSON NO.3 FOUNDED ON DECOMPOSED GRANITE

elastic (recoverable). Thus, this caisson was essentially repaired by preloading (note that the design load was only 26 MN).

The results of the first two load tests were used to estimate the load-deflection behavior of the last caisson, before the load test was performed. Using the skin friction resistance for Pile 1 and a range of base moduli the performance of the caisson was estimated using the T-Z method proposed by Reese (1964). The results of the analysis are compared with the measurements on Figure 10. The analyses indicate base moduli for the decomposed granite in the range of 150-250 MPa. The lower values would also account for time dependent deformations as well.

CONCLUDING REMARKS

The results of the load tests have proven unexpectedly high capacities for caissons founded in weathered rock. For the decomposed mica schist minimum allowable base pressures of 0.8-1 MPa are indicated although higher values could be justified. It is surmised that the preparation of the base and potential disturbance before concreting are the main reasons for differences of observed performance.

The load tests on the three caissons in decomposed granite illustrate the potential

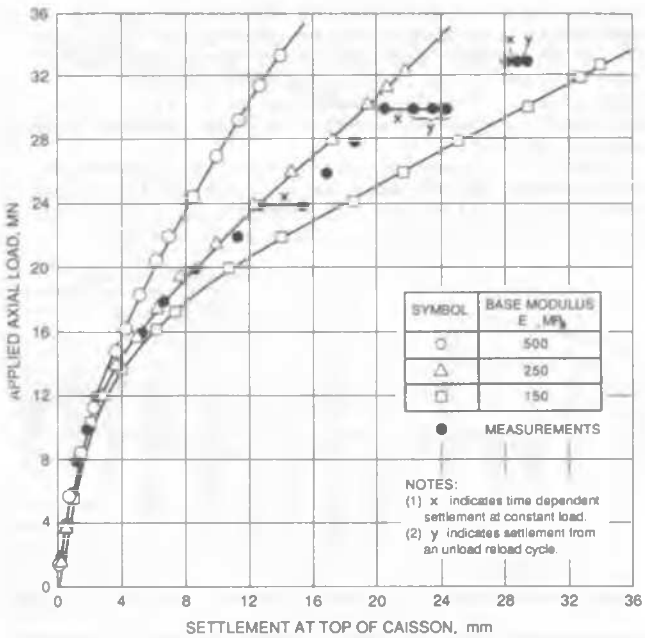


FIGURE 10 ANALYSIS OF LOAD TEST DATA: CAISSON NO.3

for high skin resistance that can be developed in very dense decomposed granite. The presence of pockets of weathered granite below the base of the caissons can cause additional settlements, but they can be estimated and designed for, using parameters for decomposed rock moduli and socket resistances presented earlier.

REFERENCES

1. Peck, R. B. (1976), "Rock Foundations for Structures," Proc. ASCE Specialty Conference on Rock Engineering for Foundations and Slopes, Vol. II, pp. 1-21.

2. Reese, L. C., (1964), "Load versus Settlement for Axially Loaded Piles," Proc. Symposium on Bearing Capacity of Piles, Part 2, Central Building Research Institute, Roorkee, pp. 18-38.

3. Woodward, R. J., Gardner, W. S., and Greer, D. M. (1972), Drilled Pier Foundations. McGraw-Hill Book Co., Inc., New York, N.Y.